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APPLICATION GUIDE FOR ELECTRICAL RELAYS FOR AC SYSTEMS

PART VII FREQUENCY RELAYS

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Indian Standard
APPLICATION GUIDE FOR ELECTRICAL RELAYS FOR AC SYSTEMS
PART VII FREQUENCY RELAYS

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APPLICATION GUIDE FOR ELECTRICAL RELAYS FOR AC SYSTEMS

PART VII FREQUENCY RELAYS

0. FOREWORD

0.1 This Indian Standard (Part VII) was adopted by the Indian Standards Institution on 17 April 1972, after the draft finalized by the Relays Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 Modern power systems are designed to provide uninterrupted electrical supply, yet the possibility of failure cannot be ruled out. The protective relays stand watch and in the event of failures, short-circuits or abnormal operating conditions help de-energize the unhealthy section of the power system and restrain interference with the remainder of it and thus limit damage to equipment and ensure safety of personnel. They are also used to indicate the type and location of failure so as to assess the effectiveness of the protective schemes.

0.3 The features which the protective relays should possess are:

a) Reliability, that is, to ensure correct action even after long periods of inactivity and also to offer repeated operations under severe conditions;

b) Selectivity, that is, to ensure that only the unhealthy part of the system is disconnected;

c) Sensitivity, that is, detection of short-circuit or abnormal operating conditions;

d) Speed to prevent or minimize damage and risk of instability of rotating plant; and

e) Stability, that is, the ability to operate only under those conditions that call for its operation and to remain either passive or biased against operation under all other conditions.

0.4 The frequency of ac voltage of a power supply network is normally maintained constant at the declared frequency and within statutory limits of variation. In conditions of emergency plant outage, excessive overloading of the network, short-circuits in the system, etc, large variations in frequency occur and it is desirable to provide means of frequency protection. Excessive or rapid variation of frequency causes variety of

damage to generating plant, damage to industrial machinery, burnouts of domestic appliances, dislocations in traffic signalling systems, etc. In certain circumstances they also result in total power failure. With the increase in interconnected power systems, large variations in frequency are likely to result in heavy damage to electrical systems and equipment, and necessity has, therefore, been felt of preparing an application guide for frequency relays for power systems.

0.5 This guide has been prepared to evaluate a variety of considerations associated with frequency based protection. The technique of application of frequency relays is still being developed and therefore no attempt has been made to standardize the schemes of application of frequency relays.

0.6 It is emphasized that this guide has been prepared to assist in application rather than to specify the relay to be used. It deals only with the principles of application of frequency relays and does not deal with the selection of any particular scheme. The actual circuit conditions in all probability may be different from those given in this guide.

0.7 In the preparation of this guide, considerable assistance has been derived from several published books and technical papers and from manufacturers' trade literature.

0.8 This guide is one of the series of Indian Standard application guides for electrical relays for ac systems. A list of standards so far prepared in this series is given on P 20.

1. SCOPE

1.1 This guide (Part VII) deals with the application of frequency relays covered by IS : 3231-1965*.

1.2 It does not cover frequency relays used for:

a) regulating frequency of emergency generating sets, portable diesel or petrol generating sets, etc; and

b) field switching and synchronizing of synchronous machines.

2. TERMINOLOGY

2.0 For the purpose of this guide the following definitions, in addition to those given in IS : 1885 (Part IX)-1966† and IS : 1885 (Part X)-1968‡, shall apply.

2.1 Overfrequency Relay — A relay which operates when the characteristic quantity (the frequency) rises to or changes through the setting value above the rated frequency of the relay.

*Specification for electrical relays for power system protection.

†Electrotechnical vocabulary : Part IX Electrical relays.

‡Electrotechnical vocabulary : Part X Electrical power system protection.

2.2 Underfrequency Relay — A relay which operates when the characteristic quantity (the frequency) falls to or changes through the setting value below the rated frequency of the relay.

3. GENERAL FEATURES

3.1 Input — The energizing quantity of a frequency relay is a single alternating voltage which should be equal in magnitude to the rated voltage of the relay. The relay response depends upon the frequency of the alternating input voltage by virtue of its electrical circuit being tuned to resonance.

3.2 Operating Principle — The internal circuit of a typical electromechanical frequency relay consists of two series resonant branches, both connected in parallel across a voltage source. The resonant frequency of one branch circuit is fixed and the tuning is flat in the vicinity of the rated frequency. The complimentary branch contains a tapped or continuously variable inductance and the frequency can be sharply tuned to resonance. If the frequency is within the non-operating zone, the currents in the two branches are adjusted to swing in phase and the relay does not operate. As the frequency approaches the operating zone, a phase difference sets up in the branch currents and the relay operates.

3.3 Movement — Various movements, such as electromagnetic, ferraris, electrodynamic, induction and permanent magnet moving coil, are employed in the frequency relays. There are many variants. However, among the electromechanical relays induction movement is the most widely used in the frequency relays.

3.4 Classification — Frequency relays discussed in this guide fall in the following two broad classes based on the operating time characteristic:

a) Relays employing the time delay movements, such as the induction disc movement; and

b) Relays employing fast acting movements, such as the induction cup movement, permanent magnet moving coil, ferraris and electrodynamic movements.

4. CHARACTERISTICS

4.1 Time-frequency characteristic curve of frequency relay indicates the time of operation of the relay when a voltage of constant frequency and sinusoidal waveform is applied to the relay. A typical illustration for an induction disc relay is shown in Fig. 1. It is presumed here that the constant frequency applied is sufficientlynear the setting. In practice, however,

the relay operation occurs by the frequency changing through the setting point, that is to say it is not constant. The effect of changing frequency on the operating time can be observed if the characteristic is plotted showing the operating time against a constant rate of change of frequency. Such a characteristic is illustrated in Fig. 2. The operating time measured is from the instant the frequency equals the setting of the relay while it changes at a constant rate.

4.2 The actual frequency obtaining at the time the relay has completed operation, in response to any given rate of change of frequency can be found from a characteristic showing the integral change of frequency in hertz against the rates of change of frequency in hertz per second. A typical illustration for underfrequency relay is shown in Fig. 3. The broken curve in Fig. 3 illustrates the eventual frequency that will result if the opening time of circuit-breaker is added to the relay operating time.

5. SETTING RANGE

5.1 The setting range available on most frequency relays is about 8 to 12 percent of the rated frequency. They are mostly continuously adjustable. However, some models are found with fixed setting up to a maximum of 7 values. The accuracy that may be achieved in the setting is of the order of $\pm$ 0·1 Hz. The manufacturer may be consulted regarding the actual accuracy of setting.

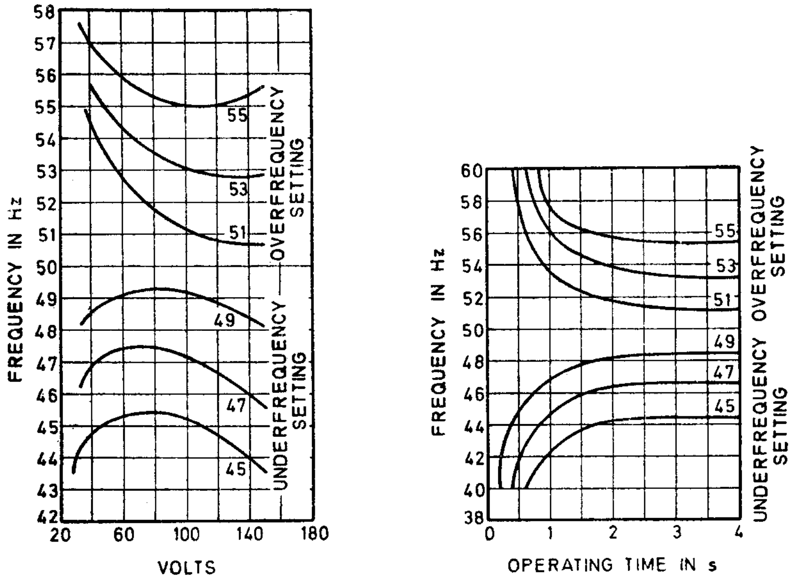
5.2 Three types of setting arrangements are available, namely:

a) Fixed setting,
b) Specified number of tapped settings, and
c) Continuously adjustable setting.

6. EFFECT OF VOLTAGE VARIATION

6.1 Variation in the magnitude of the voltage fed to a frequency relay may, in certain types, have notable effect on the setting value calibrated at the rated voltage. A curve showing change in the setting with respect to the change of voltage should be obtained from the manufacturer of the relay to examine an application of a particular relay. This is illustrated in Fig. 4.

6.2 Transient voltage variations caused by blowing of a fuse in the voltage circuit wired to a frequency relay and manual or automatic switching of an ac supply are likely to cause mal-operation of an induction cup frequency relay. This difficulty may be overcome by connecting an auxiliary relay having approximately 0·1 second delay on pick-up to delay the signal of the frequency relay. Frequency relays with incorporated auxiliary delay relay are available which can be employed for direct tripping control. If, however, an auxiliary time delay scheme is not employed internally for tripping commands, it is usually adequate to supplement externally an auxiliary relay with intentional delay.



1A Frequency Voltage Characteristic

1B Frequency Operating Time Characteristic

FIG. 1 CHARACTERISTICS OF INDUCTION DISC FREQUENCY RELAYS

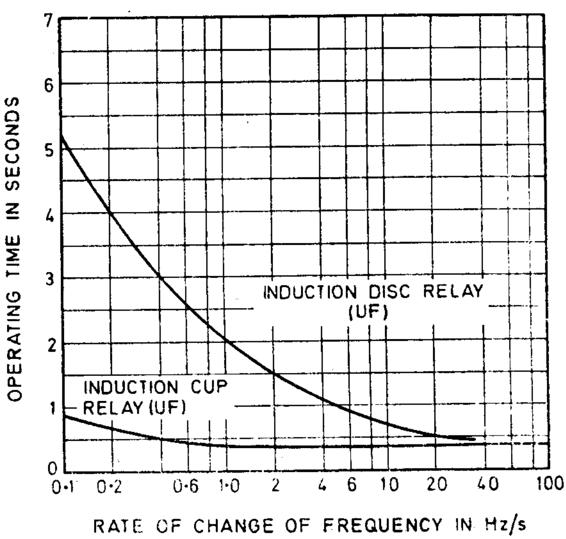


FIG. 2 EFFECT OF CHANGING FREQUENCY ON OPERATING TIME OF FREQUENCY RELAY

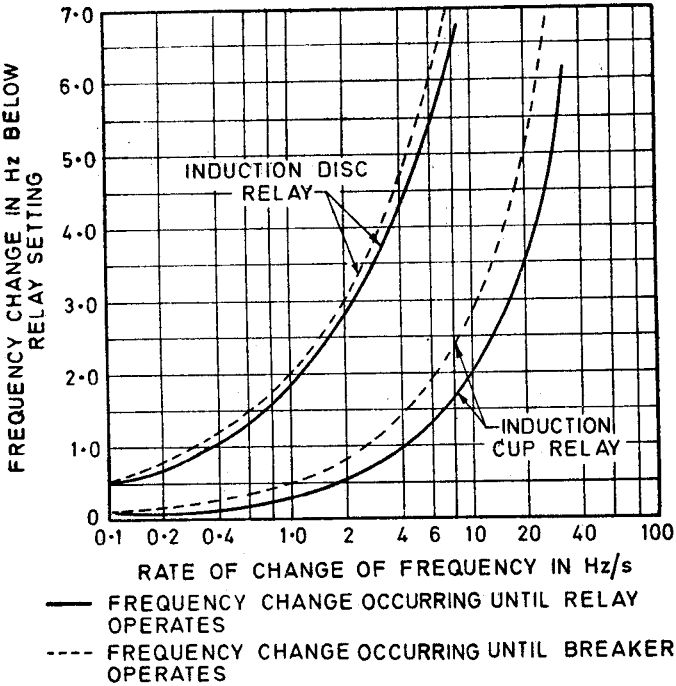


FIG. 3 INTEGRAL CHANGE OF FREQUENCY WITH RATED CHANGE OF FREQUENCY FOR UNDERFREQUENCY RELAY

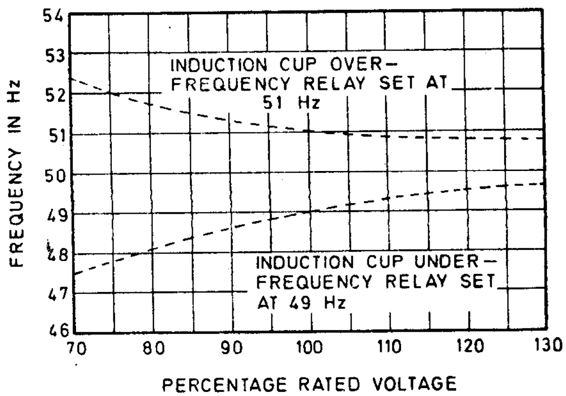


FIG. 4 CALIBRATION CHANGE WITH VARIATION OF VOLTAGE

6.2.1 The induction disc frequency relay is immune to transient voltage variations by virtue of its movement.

7. EFFECT OF TEMPERATURE VARIATIONS

7.1 The calibration of a frequency relay alters with variation in temperature. The deviation in calibration is of the order of 0·3 percent to cite an indicative value of the effect. In any particular application the deviation should be based on specifications offered by the manufacturer.

7.2 It is recommended that in practice, a frequency relay should be calibrated after warming it up for 30 to 60 minutes by switching on its rated voltage.

8. EFFECT OF HARMONIC VOLTAGE

8.1 The harmonic frequency voltage component in the energizing voltage affects the calibration of a frequency relay. A typical deviation is 0·1 Hz for a harmonic content of 10 percent. In any particular application, the deviation should be obtained from the manufacturer's specification.

8.2 The third and the major harmonic in the energizing voltage of frequency relay is eliminated when the relay is connected line-to-line across a 3-phase star-connected secondary of a voltage transformer. The higher harmonics, the fifth and the seventh, may be present but only in relatively small proportions. Energizing voltage derived from line-to-neutral or single-phase connected secondary of a potential transformer is not recommended for connecting to a frequency relay.

9. EFFECTS OF FREQUENCY CHANGES

9.1 Frequency variations are of two categories. In the first, the frequency merely drifts at a very low rate of change and may remain steady at any drift value for a long time. The effect of such drift may or may not be harmful to equipment. There are limits for such drift, beyond which harm begins to set in.

In the second variety, the rate of change of frequency is so quick that the frequency builds up or dwindles to extreme values unless corrective measures counteract and arrest the change. There is little control on this type of change; harmful effects build up on equipment and even the power supply may be endangered.

9.2 Drifting Frequency

9.2.1 Steam turbines, particularly those of higher output rating operating at pressure and temperature conditions of high order, are critically designed to operate at the rated speed and frequency. A small zone up and down the rated frequency is available for operation in which no mechanical damage will result except that the output will change. But as the frequency exceeds the safe zone, and moves beyond the limits, resonant vibrations will set up in the blades and metallic erosion will occur. The effect will vary from turbine to turbine; hence no guiding limits can be given. The manufacturer of turbine specifies the safe operating speeds or frequency zone and the time periods permissible for operating the turbines at unfavourable frequencies in emergencies with a view to limiting the damage to a minimum. The manufacturer should be consulted on the behavioural specifications of each steam turbine in this respect.

9.2.2 Operation of a steam turbine at damaging frequencies beyond the safe working zone will result in integrated damage to blades over recurrent intervals and ultimate reduction in life.

9.3 Accelerating Frequency

9.3.1 When load on a generator is suddenly thrown off due to tripping of a heavily loaded line circuit-breaker or a generator circuit-breaker, the turbine will accelerate before governor mechanism becomes effective. Hydraulic turbines have been known to reach 1·8 to 2·2 times the normal speed. Steam turbines may reach 1·2 times rated speed which is a critical overspeed where machine may break up.

9.3.2 Directly coupled exciters of hydraulic turbine driven generators will develop excessive voltage across commutator segments and a dc short circuit may result. The heat may melt solder in commutator segments which under centrifugal force would flare open. An open circuit may develop in the armature. Insulation between armature winding and shaft may break down and exciter bearings may get damaged. The generator field windings may develop inter-turn short circuit.

9.3.3 The rotor of steam turbine driven generator may shear, and the field windings on the rotor may get dislodged under huge centrifugal forces that develop.

9.3.4 The generator stator windings may (for both types of turbines) build overvoltage, straining the stator coil insulation. If stator earth fault occurs, a major outage follows.

9.3.5 It is customary to provide overspeed protection by means of:

a) overspeed trip device on the speed governor or a centrifugal switch,

b) a permanent magnet generator and a frequency relay, or

c) an overvoltage relay.

9.4 Decelerating Frequency

9.4.1 Frequency decelerates in a system, if there is sudden increase of load in excess of the available generation. Speed governor action follows and initiates build-up of speed to restore normalcy equated to new load. But delay in the speed governor action will result in decelerated change of frequency. If spinning reserve of generation capacity is available, conditions can be easily returned to normalcy. A spinning reserve on hydraulic turbine driven generator would help to equate load quickly but a spinning reserve on steam turbine generator can equate load only at a rate of load pick-up that can be sustained at uniform expansion of the turbine components, and the firing rate of the boilers. If this limits the load pick-up, the frequency deceleration will build up with cascade effects. It should be noted that any spinning reserve which is available will start to have a significant effect within about 5 seconds of the start of the generation deficit, depending upon the type of generation in the affected area.

The initial deceleration for a 50-Hz rated system can be estimated from the following formula on the assumptions that the load is a constant torque load and the speed governor action is not effective:

$$d = \frac{25}{H}\left(\frac{L - G}{G}\right) \text{ Hz/sec}$$

where

d = deceleration of a 50-Hz system;

H = average inertia constant of generators in operation in the disconnected section expressed in per unit value;

L = system load in megawatts, that is, total load before disconnection; and

G = system generation in operation in the disconnected section in megawatts.

A typical response of a steam turbine driven generator based on this method of estimate is illustrated in Fig. 5. The initial load is 1·0 per unit. It would be seen from the illustration that corrective action shall be taken very fast before critical frequency is reached or else the unit shall be tripped.

9.4.2 At lower than rated frequency, the output voltage of a shunt exciter without a voltage regulator collapses as the slope of the terminal voltage build-up curve of the exciter coincides with the field resistance line. This would happen when the voltage regulator is removed from service for maintenance. The generator excitation would then be in jeopardy; the generator would be removed from service by loss of field protection.

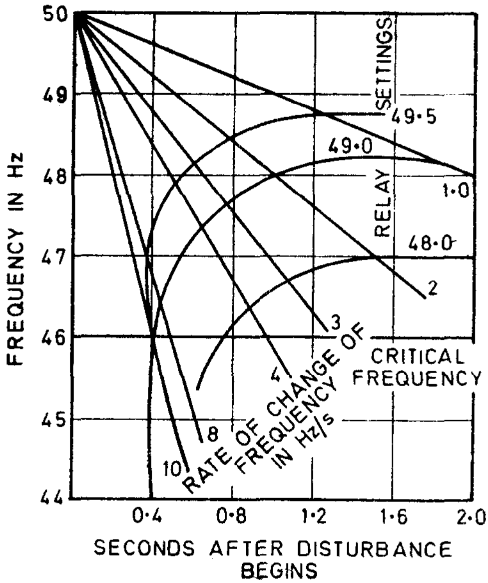


FIG. 5 TOTAL CLEARING TIME FROM DISTURBANCE

9.4.3 At very low frequency, the terminal voltage of direct coupled exciter drops which in turn reduces excitation and the internal generated voltage of an alternator. The machine is, in that case, in a danger of falling out of synchronism.

9.4.4 If the voltage regulator is in service, it will boost the exciter voltage by moving to full boost position. It shall return to normal position within about a minute or else the thermal capability of the alternator stator will be exceeded; the voltage regulator itself and the alternator field winding will be seriously overloaded.

9.4.5 A system operating at low frequency is critically in danger. A steam turbine generator unit will be in difficulty with 5 percent reduction in frequency as the boiler feed-water pump motors, coal mill motors, draft fan motors will operate with reduced output and depending on the design of the boiler the conditions will redouble until complete failure results.

In hydraulic turbine generator units the effect is not so serious on the auxiliaries even up to a frequency drop of 10 percent below normal. Along with underfrequency, undervoltage also follows which further aggravates the situation.

9.4.6 With underfrequency system undervoltage also follows. The VAR output of generator is reduced. The system deficient in VAR tends to be unstable. Motor loads in the system may trip out creating relief in the system but other plant load will be overloaded. If underfrequency is caused by a system short circuit, the various cascade effects may tear the system apart into areas each of which will have new problems. In all probability complete power failure will result in a part or the whole of the system.

9.5 Frequency relays have been applied to forestall ill-effects of the frequency changes. The available methods are described in **10** and **11**.

10. APPLICATION OF OVERFREQUENCY RELAYS

10.1 The mechanical overspeed devices mentioned earlier in **9.3.5** are not sometimes provided. Instead a permanent magnet generator is provided in the speed governor. The output voltage of the generator is connected to a fast acting overfrequency relay or overvoltage relay.

10.1.1 It is also possible that the mechanical overspeed device, if not carefully maintained and regularly tested, may fail to operate when required in an emergency. An overfrequency relay may be used as a back-up protection to the mechanical overspeed device. The relay contact for tripping is connected to trip the throttle of the turbines. The unit is shut down from the electrical side by the action of a power relay tripping in the generator direction.

10.1.2 The setting of the overfrequency relay is usually adjusted to 110 percent of the rated frequency when applied to steam turbine generator unit. Higher setting to 115 percent may be permissible for hydraulic turbine generator.

10.2 An overfrequency relay is sometime applied to protect a steam turbine generator unit against picking up overspeed in the starting operation. In the process of starting, the turbine is rolled at approximately one-third rated speed and after heating and expansion of shaft is uniform, the turbine is quickly accelerated to rated speed by raising safely through its lower critical speeds. In case it overspeeds, the throttle valve will automatically be tripped by the overfrequency relay. The setting is adjusted to 104 to 105 percent of rated frequency.

A similar situation does not arise in the case of hydraulic turbine driven generators.

10.3 The damage caused to steam turbine blades mentioned in **9.2** by drifting overfrequency operation may be checked under supervision of a induction disc or time delayed overfrequency relay connected to operate an audible alarm in the boiler and turbine control room as well as the electrical room. Remedial action may be initiated manually.

10.3.1 The setting to be adopted would be about 102 percent of the rated frequency. The actual setting should be based on the behavioural characteristic of each turbine, in consultation with the manufacturer.

11. APPLICATION OF UNDERFREQUENCY RELAYS

11.1 Damage is caused to steam turbine blades as mentioned in **9.2** by drifting underfrequency operation. A supervisory protection as mentioned in **10.3** is not sufficient in this respect. A generator operating in a system with slight overfrequency and slight overvoltage is indicative of a stable system. But with a slight underfrequency and undervoltage the system tends to be unstable. Faster protection is in this case desirable, not only to forewarn but to take corrective action quickly before conditions worsen.

11.1.1 An induction cup type or fast operating underfrequency relay can be employed not only to project instantaneous audible alarm but also to relieve suitable loads with measured time delay. The objectives to be secured depend upon the system configuration.

11.2 If the supply to a synchronous motor is interrupted, it is essential that the motor circuit-breaker is tripped as quickly as possible, if there is any possibility of the supply being either automatically restored or restored without the knowledge of the machine operator. This is necessary in order to avoid the possibility of the supply being restored out of phase with the motor generated voltage. The underfrequency relay will cater for the condition of the supply failing when motor is on load, causing the motor to decelerate fairly quickly.

11.2.1 A fast operating underfrequency relay is employed to disconnect the motor on loss of supply. The voltage fed to the underfrequency relay should be derived from the motor side so that on failure of the mains supply the motor continues to feed a voltage of underfrequency to the relay.

11.2.2 If the supply is received on a long feeder, which also caters to non-synchronous loads along with the synchronous motor load at the receiving end, an instantaneous auto-reclosing control may be provided at the sending end, only when the protection mentioned earlier is employed.

11.3 If supply fails in a station, undervoltage relays are employed to switch over communication equipment to alternative source of supply. However, when undervoltage and underfrequency conditions occur due to excess of load over generation, communication equipment would continue to be supplied from the affected supply. The communications are most likely to be impaired in this situation particularly if electronic valves constitute its components.

11.3.1 An induction disc or time delay underfrequency relay may be used to switch over communications to an alternate supply. The need of an undervoltage relay mentioned in **11.3** cannot, however, be eliminated as the underfrequency relay will not operate for total supply failure.

11.4 Underfrequency relay of the fast operating type is a reliable device for switching in system fault recorders in a few select locations in a system as records of a disturbance affecting the whole system are required on a comparable basis. The other types of protective relays may be used for this purpose but at a disadvantage that all of them will not simultaneously switch all the recorders into action. As underfrequency would be a common reference at all places, recorders switched by underfrequency relays would almost start at the same time. The records so obtained would be comparable and very useful in analyzing the sequence of a disturbance.

11.5 An industrial consumer having his own generating plant to meet part of his load and receiving his balance needs of power from a supply organization (*see* Fig. 6) can employ underfrequency relay to protect his generating plant if supply from the supply organization system fails. The industrial generators will begin to feed power to the other system and underfrequency will result. A similar case arises if the supply organizations circuit-breaker at sending end trips, the line is tapped for supplying other loads and the receiving end circuit-breaker at the industrial bus-bar does not trip. The industrial generation can be saved in these cases by tripping the receiving end circuit-breaker on the supply organizations line at the industry's bus-bar by an underfrequency relay. If the generation is not sufficient to meet all the loads, the same underfrequency relay may be used to trip feeders supplying non-essential load along with the tie circuit-breaker on the supply organizations line.

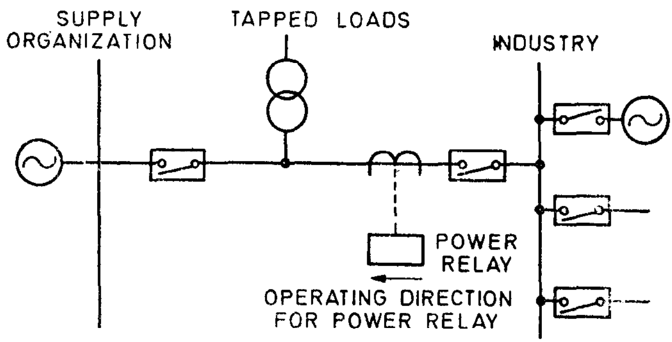


Fig. 6 Application of a Frequency Relay in an Industrial System Having its Own Generation and also Drawing Power from a Supply Organization

11.5.1 The setting of the underfrequency relay will be fairly near the rated frequency. It sometimes happens that the supply organizations operating frequency may be slightly below the rated frequency and within allowable limits. The industry's generators will follow the frequency as they cannot correct it. There is then a chance of mal-operation of the underfrequency relay if the setting is skirting near the operating frequency. To prevent such mal-operation, the setting and the supply to the relay should be carefully selected.

11.6 In a large power system comprising a number of generating stations producing energy from water head or fuels and having a number of switching and transforming stations interlinked in any manner by high voltage transmission lines, a state of underfrequency and consequently unstable operation may set in if excess load over generation occurs due to loss of generation or tripping of a transmission line initiated by a short circuit somewhere in the system which may be cleared by mal-functioning or slow operation of the conventional protective devices. There may be a failure of circuit-breaker, or a lightning arrester. Instances are sufficient of system totally shutting down with a fast frequency decay.

11.6.1 Fast frequency decay may be arrested by automatic load limiting in the system.

11.7 Load limitation may be done in the following ways:

a) Tripping the feeders — this is the major primary solution;
b) Splitting the system into areas, which in themselves are self-sufficient in generation as far as the load in the area is considered. This has a secondary value; and
c) Combination of both (a) and (b).

11.7.1 In devicing these measures, it is necessary to bear in mind intimately:

a) the knowledge of the power system itself as regards its physical outlay, the relationship of excess generating areas with the excess load areas, the line loadings, etc;
b) the operating limitations of the equipment particularly the generating plant and the transformer equipment; and
c) the characteristic of the loads.

11.7.2 These requirements will differ in each system. No standard arrangement can, therefore, be offered. Mostly it will be necessary to devise suitable arrangement which meets the needs of any particular system.

11.8 Feeder Tripping

11.8.1 Knowing the nature of loads and taking account of any commercial agreement with individual consumer, it will be possible to divide feeders into following or similar classes.

11.8.1.1 Feeders carrying loads which are essential to be maintained at all times. This usually covers supplies to hospitals, water works and industrial loads where the process carried on cannot be interrupted, as such interruption would involve prolonged shut-down for days before the plant can be returned to service.

11.8.1.2 Feeders carrying important loads which if interrupted would result in loss of material or temporary inconvenience, but may be returned to normalcy without necessity of prolonged outage.

11.8.1.3 Feeders carrying general loads which are not affected by interruption beyond an inconvenience.

11.8.2 The analysis will help to assess the load relief obtainable according to the type of load. The classified feeder loads may then be connected in the load limitation scheme according to desired sequence. Three load limiting scheme for feeder tripping are generally used.

11.8.2.1 In the first scheme, the number of underfrequency relays is the same as the number of groups of feeders. Each feeder group will be tripped by the associated frequency relay through a multicontact tripping relay. Each relay will have its own frequency setting and the settings can be graded with respect to the total relief required. In this scheme loads can be tripped all over the system one after other and if system frequency recovers, the relays will reset and no further tripping will occur.

An illustration of this scheme is shown in Fig. 7. If frequency relays are of the draw-out type, it is a very simple matter to change any particular feeder group to control of other relay having different frequency setting as the relays can be interchanged. If the rate of frequency change is relatively slow, the load relief will be time-spaced automatically by the time rate of frequency change permitting the system to recover at any time without tripping any unnecessary load. If on the contrary the deceleration is fast, invariably all relays will trip out feeders under their control, and the system will recover after full relief of load. The scheme is flexible and self-contained.

11.8.2.2 The second scheme consists of one underfrequency relay and a timer with as many time contacts as the number of feeder groups to be tripped. Each time, the contact of the timer will energize a multicontact tripping relay for tripping all feeders in a group. One underfrequency relay per scheme will be required at each station and each relay may have a different frequency setting.

An illustration of this scheme is shown in Fig. 8. Load relief at any given station will be obtained at fixed time intervals according to the settings given to the timer after the frequency has touched the setting of the particular relay. If the deceleration of frequency in the system is relatively slow, only the initial load relief obtained instantaneously by operation of the underfrequency relay will be time-spaced automatically

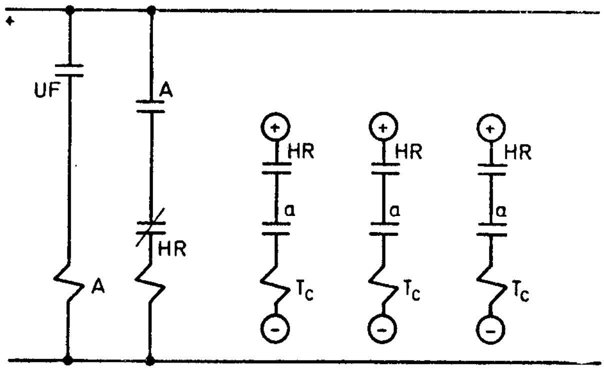
according to the relief change frequency. This relief would not be ample as only one relay would be operating in the system at any time. The relief stages to be timed out by the timer would be independent of the rate of change of frequency that demands the relief. More load than necessary will be relieved before system would begin to recover. If the deceleration is fast, the scheme will take long time to respond.

In this scheme feeder groups can be rotated to trip in the sequence of the time settings by inserting a rotary switch to connect the timer contact orders cyclically to the tripping relays. This means that interruptions to the consumers will be cyclically given in successive emergencies.

11.8.2.3 The third scheme consists of a combination of parts drawn from **11.8.2.1** and **11.8.2.2.** A variety of intricate combinations is possible. Attention to the needs of particular system, the reliability of the scheme adopted and its flexibility to operation and testing would ultimately matter.

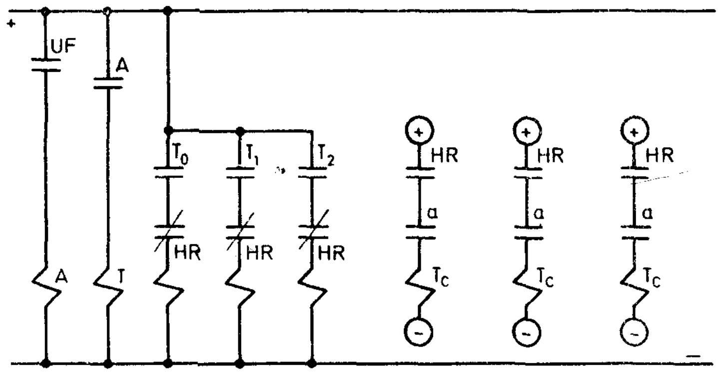
12. TESTING

12.1 For the purpose of testing frequency relays, a dc or ac motor generator set may be used if available. Alternatively an electronic frequency generator may be used. The latter is usually portable and facilitates testing of frequency relays at site.



UF = Underfrequency relay
A = Auxiliary relay
HR = Hand reset auxiliary tripping relay
Tc = Tripping coil of breaker
a = Make contact of breaker

FIG. 7 APPLICATION OF UNDERFREQUENCY RELAY FOR FEEDER TRIPPING — NUMBER OF RELAYS IS THE SAME AS NUMBER OF FEEDERS



UF = Underfrequency relay
A = Auxiliary relay
T = Timer solenoid (T_0 Instantaneous)

HR = Hand reset tripping relay
T_C = Trip coil of circuit-breaker
a = Make contact of breaker

FIG. 8 APPLICATION OF UNDERFREQUENCY RELAY FOR FEEDER TRIPPING — ONE RELAY AND A TIMER HAVING SAME NUMBER OF CONTACTS AS THE NUMBER OF FEEDERS

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1885 (Part IX)-1966 Electrotechnical vocabulary : Part IX Electrical relays

1885 (Part X)-1968 Electrotechnical vocabulary : Part X Electrical power system protection

3231-1965 Electrical relays for power system protection

3637-1966 Gas-operated relays

3638-1966 Application guide for gas-operated relays

3842 (Part I)-1967 Application guide for electrical relays for ac systems : Part I Overcurrent relays for feeders and transformers

3842 (Part II)-1966 Application guide for electrical relays for ac systems : Part II Overcurrent relays for generators and motors

3842 (Part III)-1966 Application guide for electrical relays for ac systems : Part III Phase unbalance relays including negative phase sequence relays

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3842 (Part VI)-1972 Application guide for electrical relays for ac systems : Part VI Power relays

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